Executive Summary

In recent years, there has been increasing interest in the ability of travel demand models to estimate travel not only for the average weekday, but for different periods within the day. Travel demand models are increasingly required to be analysis tools for a broad range of issues on transportation policy and project alternatives. These issues often require detailed analysis, not only spatially, but temporally as well. This report provides documentation on methods used in U.S. urban areas to handle the issue of time of day in their travel demand models. Commonly used practices are described, the most innovative methods used by metropolitan planning organizations and states are documented, and emerging approaches are described as well.

■ Standard Approaches

Trips occur at different rates at different times of the day. Typically, there are one or more peaks in daily travel. The dominant weekday peak periods are in the morning (AM peak period) and in the late afternoon (PM peak period). A peak period can be characterized by its maximum trip rate (in trips per unit time). The peak hour is the hour during which the maximum traffic occurs. The portions of the peak before and after the peak hour are called the "shoulders of the peak".

The time at which travel occurs and, more specifically travel peaking intensity and duration are critical to the estimation of a number of important travel performance measures, including speeds, congestion, and emissions. Yet peaking and time of travel are included in the traditional travel model in highly approximate ways, typically by developing peaking or time-of-day factors from observed data and assuming the same patterns will persist in the future.

A time-of-day factor (TODF) is the ratio of vehicle trips made in a peak period (or peak hour) to vehicle trips in some given base period, usually a day. Time-of-day factors are most commonly specified as exogenous values that are fixed and independent of congestion levels. If applied prior to trip assignment these time-of-day factors are usually determined from household activity/travel survey data and from on-board transit and intercept auto surveys, with a separate TODF for each trip purpose. If applied after assignment, the peaks' timing and duration are generally estimated from traffic data (e.g., 24-hour machine counts on streets and highways, transit counts, or truck counts), perhaps interpreted and adjusted based on data from special studies (e.g., travel surveys of workplaces and customer-serving businesses in a particular area or driveway counts at major activity centers). Occasionally, time-of-day factors are borrowed from other areas and adjusted during the model calibration process.

There are several commonly employed methods for accounting for time of day of travel in the four-step travel modeling process. To proceed from the initial daily trip generation estimates to the volume estimates by time period, average daily travel estimates must be converted to trips by time period. This time-of-day assignment can happen at four places in the modeling process:

- After trip assignment;
- Between mode choice and trip assignment;
- Between trip distribution and mode choice; and
- Between trip generation and trip distribution.

These four time-of-day assignment approaches are described in the following paragraphs. Table ES.1 summarizes their applicability, level of effort and data required, and their limitations and advantages.

Time-of-Day Assignment after Trip Assignment

In this method, the assigned daily link volumes are factored to produce volume estimates by time of day. This method is the simplest and probably the most commonly used. The post-assignment static technique uses a daily traffic assignment as a basis. In its simplest form, peak hour factors (usually in the range of 8 to 12 percent) are used to reflect peak period link-level travel demand. In this approach, the daily assigned volumes are multiplied by the peak period factor to estimate peak period demands. The technique can be refined to reflect different peak hour percentages. A directional split percentage (e.g., 60 percent), derived from observed traffic conditions, is applied to obtain link-level peak volumes.

This procedure yields only a rough approximation of link- or corridor-level peaking though it may suffice for smaller MPOs where the duration and intensity of congestion are limited. In general, there is little reason to expect specific facilities to exhibit the same peaking patterns or characteristics as "regional averages," and application of a fixed TODF may be a significant source of error.

Time-of-Day Assignment between Mode Choice and Trip Assignment

This widely used procedure factors the purpose- and mode-specific, daily trip tables produced by the mode choice model. These trip tables are then used as inputs to time period-specific trip assignments. For example, three time periods may be used: morning peak, afternoon peak, and off-peak. Peak hours, rather than peak periods, are modeled in some regions. Daily traffic volumes are produced by adding up the results of the morning, afternoon, and off-peak period traffic assignments.

The process for preparing peak hour directional trip tables requires the factoring of the person or vehicle production-attraction formatted trip tables to peak hour (or period) origin-destination formatted vehicle trip tables. The data required include an hourly

distribution of trips across the day. These should be by trip purpose, usually grouped into home-based work, home-based non-work, and non-home-based. From this diurnal distribution of trips, factors are developed which represent the percentages of the trips (by purpose) during each hour and for each direction, production-to-attraction or attraction-to-production. The hourly distribution is developed from local travel survey data. The production-attraction formatted trip tables are multiplied by the appropriate factors and transposed where necessary to produce balanced origin-destination trip tables.

Time-of-Day Assignment between Trip Distribution and Mode Choice

In this method, the total daily person trip tables by purpose are divided into total person trip tables by purpose for each time period. These estimates are then used as inputs to time period specific mode choice models. Directional splits (e.g., home to work vs. work to home) must be determined as part of this process. If peak period to peak hour conversions are also done at this point, a second set of factors is used.

Time-of-Day Assignment between Trip Generation and Trip Distribution

This process factors the daily trip productions and attractions by purpose and zone to produce trip end estimates by purpose and zone for each time period. These estimates are then used as inputs to time period specific trip distribution and mode choice models. Directional splits (e.g., home to work vs. work to home) must be determined as part of this process. If peak period to peak hour conversions are also done at this point, a second set of factors is used.

■ Innovative Approaches

There are several innovative methods used by MPOs or state agencies that go beyond the relatively simple factoring methods described in the previous section. These “Peak Spreading” methodologies work within the confines of the current “four-step” modeling process. The peak spreading process addresses the problem that projected demand exceeds capacity in certain corridors during the peak period and that failing to account for the excess demand results in a flawed assessment of travel conditions in the future. Three approaches to improving the time-of-day modeling process are presented in this report:

- Link-based peak spreading
- Trip-based peak spreading
- System-wide peak spreading

These three peak spreading approaches are described in the following paragraphs. Table ES.2 summarizes their applicability, data required, and their limitations and advantages.

Link-Based Peak Spreading

This approach accounts for congestion at the link level and diverts trips to the "shoulder" hours on either side of the peak. One of the most well known examples of this method was developed for Phoenix, Arizona. The result was a set of significantly more realistic estimates of future traffic volumes and speeds on congested highways, as well as more realistic estimates of regional travel performance measures.

The Phoenix study was based on data collected from 49 corridors in Arizona, California, and Texas. These data provided relationships between peak hour and peak period volume as a function of facility type and volume/capacity ratio in the peak period. The peak spreading procedure was applied as part of a peak period (typically three hours) equilibrium assignment. As each link is considered, in turn, during the equilibrium assignment's travel time updating, peaking factors representing the ratio of peak hour volume to peak period volume are computed using a decreasing function of the link three-hour volume-to-capacity ratio. The peaking factor function was estimated with time series and/or cross-sectional vehicle count data. The peak hour volume corresponding to this peaking function was used to estimate revised travel times during each iteration of the equilibrium assignment procedure.

Trip-Based Peak Spreading

An alternative to the link-based peak spreading approach is a trip-based approach that spreads the number of trips for an origin-destination interchange that occur in the peak period or peak hour. Trip-based peak spreading approaches recognize the overall constraint of future highway network system capacity (by time of day) by limiting the assignment of trips to that network based on the overall capacity of the future network at selected congested links. This approach was applied in the Tri-Valley model in Contra Costa County, CA and in the Central Artery model in Boston, MA.

A variation of this approach was applied in the Washington, D.C. model. This peak spreading model was calibrated using household survey data and used a stratification of data by trip purpose. The prevailing assumption is that the non-work trip purposes would have flatter peaking than the work and university trip purposes. This procedure estimates the percentage of peak period travel at the vehicle trip interchange level that occurs during the peak hour as a function of two variables including congested travel time minus free-flow travel time; and trip distance.

System-Wide Peak Spreading

This method includes a system-wide peak spreading approach that has been implemented by the Volpe National Transportation System Center (VNTSC) within a modeling framework applied in evaluating Intelligent Transportation Systems (ITS). This peak spreading approach considers the system-wide excess travel demand and delay and distributes excess travel demand between the individual travel hours that comprise the peak period. This approach is neither link-specific nor trip-specific;

because it was designed to model the travel impacts of ITS deployment, it assumes that a significant amount of travel information is available to travelers and thus the traveler's temporal response to congestion can be modeled on a system-wide basis rather than on a trip-specific or link-specific basis.

Emerging Approaches

The peak spreading approaches described in the previous section do not fully address travel response to system changes and, thus, cannot be used to fully analyze policy changes or effects of travel demand management actions. Emerging approaches intend to model traveler response to congestion in much the same way that mode choice is modeled. While there are no working models at present, there is potential for implementation of this procedure within the traditional four-step modeling process.

Several MPOs, including MTC (San Francisco Bay Area), Metro (Portland, Oregon), and SACOG (Sacramento) have proposed explicit time choice components for proposed travel demand model system updates. These proposals include the following:

- A model of time of day choice that predicts the period of travel as a function of variables such as free flow and congested travel times, transit level of service, trip purpose, and area type variables. This can be a logit model that could be applied after mode choice.

- A model of whether peak period trips occur in the peak hour or not. This can also be implemented as a logit model as part of a "variable demand" multiple vehicle class assignment. Use of a variable demand assignment guarantees that the results of the peak hour models are in accord with the congestion resulting from the assignment. Off peak vehicle trips would still be assigned using a traditional static demand assignment.

- A model based on a combination of traditional TOD factors and a binary time-of-day choice model. The choice model will be based on congestion represented by peak/off-peak travel times, delays, etc. The underlying hypothesis is that relatively higher congestion during peak time results in a higher likelihood of off-peak choice.